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Abstract. Short-pulse, ultra-intense lasers generate hot electrons at the cone tip in a Fast Ignition target. Core heating and cone-wire experiments find that about 20% of the incident laser energy is coupled into a target, but do not characterize electron propagation direction, a critical parameter for ignition. Previous studies using flat foils suggest they propagate forward, diverging by ~40°. Buried cone targets—conical cavities in multilayer metal foils—were developed to allow divergence measurements in an FI relevant geometry. Preliminary results show increased electron divergence in a 30 μm diameter cone tip which disappears for 90 μm diameter tips. Implications of the experiment are discussed.

1. Introduction

A defining feature of the fast ignition concept for inertial fusion energy is ignition of the fuel, during the short interval of maximum density, by energy injected using a separate short-pulse laser. [1] A reentrant cone was added to the originally proposed configuration to reduce the required energy transport distance. [2] The tip of that cone must be narrow to avoid interfering with the fuel compression. So the electrons must be launched from a confined volume. Forward-going electrons generated in this way have been extracted from a cone tip with attached Cu wire. [3] Laser to electron energy coupling has been shown to be ~15% for the largest diameter wire (40 μm). This is very similar to ~20% determined from integrated core-heating experiments. [4, 5] But in both cases, the spread of the electrons as they leave the cone tip, critical for the heating of a small ignition volume, could not be determined; the former because the electrons are artificially confined to the cone-wire assembly by electrostatic fields at its outside surfaces, and the latter because of lack of a spatially resolving electron diagnostic.

Divergence of laser generated electrons has been characterized using a flat interface, aluminum as the plasma, and the *K*-edge fluorescence from a buried Cu layer to determine their number and spread (Fig. 1a). [6] The typical electron divergence angle is 40°, apparently increasing with laser intensity. [7] In principle, this data should also apply to electrons generated inside a cone; a typical fwhm laser spot is ~10 μm diameter and, at the Titan laser where our experiments have been performed, anecdotal evidence suggests a pointing accuracy of ~5 μm; these dimensions are small enough to routinely land the laser energy on the 30 μm diameter flat cone tip. Recent measurements showing a reduction of

~5X in coupling from cone tip to wire as the cone wall thickness increases, [8] as well as PSC PIC modeling showing strong perturbations caused by cone wall plasma from only nominal prepulse energy, [9] strongly suggested that electron divergence from cones might be very different than from flats.

In this paper we test that thesis with new buried cone targets that allow electron propagation characterization while approximating fast ignition conditions—a plasma-free conical space embedded in the blow-off from a compressed shell.

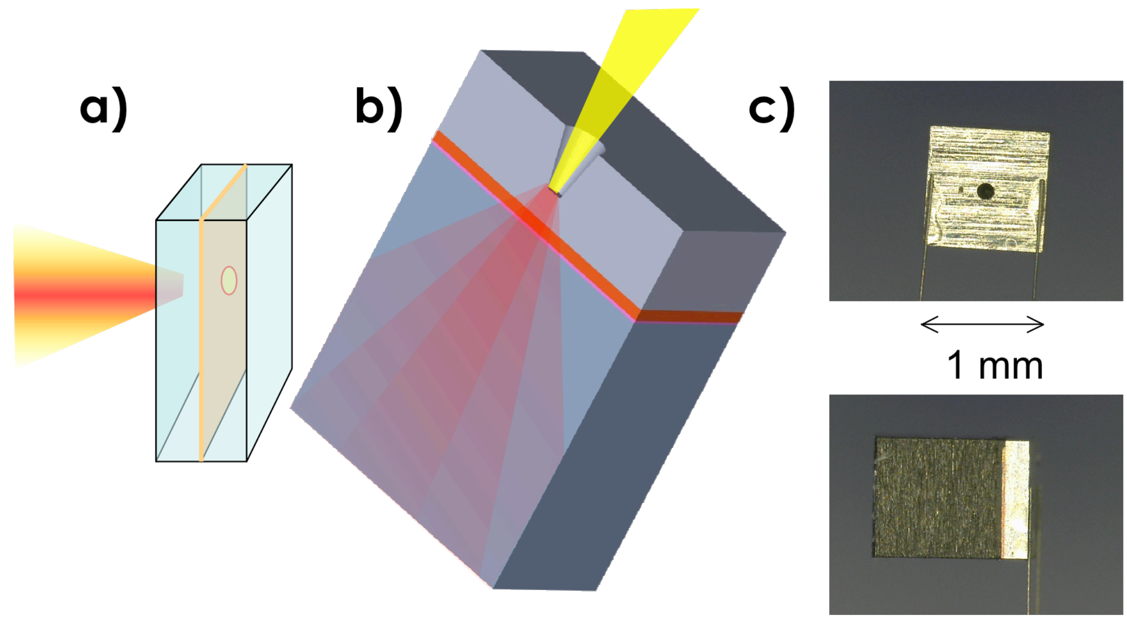

Figure 1: Targets used for measurement of electron divergence. a) Flat Al foil containing a buried Cu layer, b) Conical cavity in an Al foil. The incident laser beam and resulting electron flux are overlain in yellow and red, respectively. The far side of the Al is first coated with a 25 μm thick Cu layer, and then a C block added. c) Top and side view of a buried cone target

2. Experiment

The targets were 200 μm thick Al foils plated on one side with 25 μm thick Cu to which 1 mm thick C was glue, and a cone-shaped cavity cut into the other side (Fig. 1b). The cavity walls had a 15° half-angle opening and tip diameters of 30 μm (standard for cone experiments) and 90 μm. The cavities were cut either 100 μm or 190 μm deep so that their tips were 100 μm or 10 μm from the Cu layer. They were shot at the Titan laser facility at Lawrence Livermore National Laboratory (LLNL) using ~0.7 ps, ~150 J pulses; the f/3 beam was focused to the flat tip of the cone. A water-filter-protected fast diode monitored the prepulse and an equivalent plane setup monitored the focus on every shot. [10]

3. Results

The Cu *K* fluorescence was measured using an HOPG spectrometer, [11] for total emission, a spherically bent Bragg mirror imaging 8.03 keV radiation on an x-ray ccd camera [12] with a spatial resolution ~10 μm. Only the Bragg imager data has been analyzed to date. The fluorescence images show a spot diameter very similar to those from flat foils for the cones with 90 μm diameter tips, and with larger divergence for those with 30 μm diameter [Fig. 2]. Analysis of the fluorescence partition between peak and diffuse background, between shallow and deeply buried fluor layers is underway.

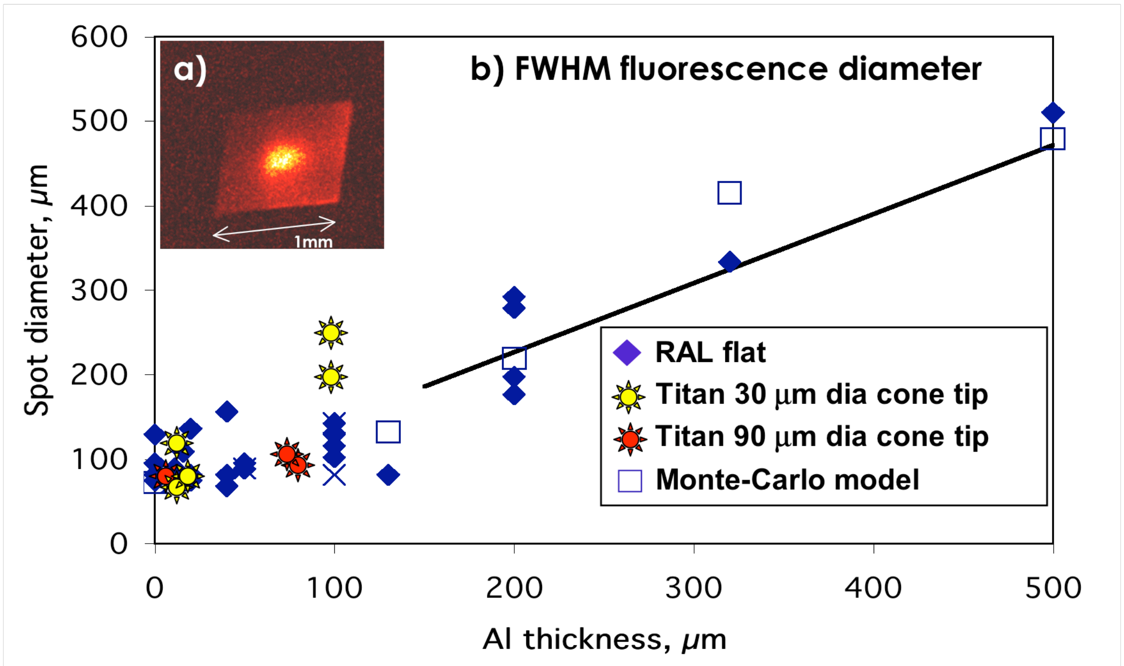

Figure 2: a) 8 keV fluorescence image from a buried cone target shown in Fig. 1 b,c. b) FWHM diameter of fluorescence from all those targets (yellow and red stars) overlaid on flat foil data (the blue diamonds) and a Monte-Carlo model (the open squares) from Ref. 6.

4. Discussion

One can see from the data in Fig. 2 that the cone walls, for the standard 30 μm diameter cone tip, clearly increased the electron dispersion; the data from ~100 μm deep fluor is substantially outside the scatter of data from the flat foils. More surprisingly, they did **not** change the spot diameter for a shallowly buried fluor layer. Aside from one large diameter outlier caused by a bad laser focus (as determined by the equivalent plane imager), they are virtually identical to each other and to the earlier flat foil results, and all ~3X larger than the 30 μm cone tip diameter only 5 μm from the fluor layer. The ~100 μm fwhm spots had been previously justified as the result of combined temperature and density gradients generating quasi-static fields [13] allowing electrons to flow out along the surface. [14, 15] That image is hard to justify when the surface is only 30 μm diameter. The flat foil data was explained in Ref. 5 with a model (the open squares in Fig. 2) in which the electrons dispersed widely enough to cause a large spot in the shallow buried fluor layer are of such low energy that they do not reach a deeper fluor. Alternatively plasma build-up inside the cone could cause electrons to be generated some considerable distance up the cone away from the tip; the PSC PIC simulation in Ref. 9 shows that even for a nominal 7.5 mJ prepulse, electron may be generated as much as 50 μm up the cone away from its tip. Analysis of the relative strengths of these spots combined with detailed modeling will be necessary to evaluate these alternatives.

5. Acknowledgements

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